

An Automated, Imaging System for Concrete Analysis

Description:

For information and research purposes, the Missouri Department of Transportation (MoDOT) performs concrete evaluations to determine the quality of newly placed concrete and to examine concrete degradation over time. A total of 16 microscopical properties of hardened Portland cement concrete are measured and characterized in a time-intensive, manual evaluation process.

Over years, the U.S. Department of Energy's Kansas City Plant (KCP), operated by Honeywell International Inc, has developed an extensive capability in image processing, pattern recognition, and system integration for use in weapons applications. For this Cooperative Research and Development Agreement (CRADA) project between KCP and MoDOT, the same technology was applied to evaluate the microscopical properties of hardened concrete.

Specific requirements to develop this new technology were:

- automated scanning of the concrete sample with precision to $\frac{1}{2}$ micron
- automated analysis of acquired imagery to calculate 16 microscopical properties of concrete according to ASTM C-457
- agreement between the results obtained with the automated system and those obtained by the human expert

The technology developed to address this problem uses a research grade compound microscope, a three-color CCD video camera and frame grabber, a high precision two dimensional stage, and a 450-MHz dual Pentium personal computer. An intense light source illuminates the surface of the concrete sample from a very low, grazing angle to accentuate the voids and improve contrast. All system components are linked via a graphical user interface that aids the operator in the image acquisition, analysis, and review processes.

The scanning and analysis processes are designed to scan and collect microscope imagery of the surface of a sample of polished concrete and to determine the microscopic properties of interest, with very little interaction from the human operator. The scanning process is performed at high precision to preclude overlaps of adjacent fields-of-view. The analysis of the acquired imagery is performed using customized image processing techniques to process the imagery and to detect voids (caused by entrained air) in the concrete. The relative percentage of the sample volume occupied by air voids compared to the other components of the concrete (paste and aggregate) is used as a measure of the quality of the concrete. In all, 16 microscopical properties (as defined by the ASTM standard and MoDOT procedures) of the concrete are estimated and used to assess the quality of the test sample.

Research Development and Technology Division

Missouri
Department
of Transportation

1617 Missouri Blvd.
P.O. Box 270
Jefferson City,
Missouri 65101

The scanning and analysis processes, performed with high consistency, offers these advantages:

- automates sample scanning and improves the speed of the scanning process
- reduces operator fatigue and error
- improves the consistency of the evaluation process
- captures and preserves the baseline knowledge used by transportation industry experts in performing the evaluation process
- provides an analysis process that is flexible and extensible to accommodate user-specific requirements

A prototype of this system was successfully completed in 2000. Additional system validation and software development is continuing to ensure that the system provides evaluation results to within a satisfactory level of agreement with the MoDOT experts. However, system hardware and software can be used as a baseline system to develop integrated analysis approaches for other applications in the concrete, transportation, or related industrial areas.

Objective:

MoDOT's Transportation Commission was the recipient of this technology. The Commission's Research group evaluates the quality of the concrete used in Missouri highways and bridges. This technology was needed to replace the previous technology that relied on a labor intensive, manual evaluation process. Further, the expertise required to perform the manual process resided in a relatively small number of MoDOT employees. As a result, the technology developed was designed to:

- reduce or eliminate the tedious aspects of the scanning and evaluation processes and to improve efficiency
- improve the consistency of the scanning process to eliminate potential errors and analysis variances due to operator subjectivity
- capture critical knowledge of the scanning and evaluation processes from a relatively small number of experts currently performing the manual process

Participants in the Partnership:

The primary KCP contact in the CRADA partnership is:

Chris Baumgart
Honeywell FM&T/NM
P.O. Box 5250
Albuquerque, NM 87185-5250
Telephone (505) 844-2585 (fax - 1915)
Email cbaumgart@kcp.com

Technology Transfer Process Used/Innovations:

A CRADA was initiated in 1998 between MoDOT and KCP to accomplish this technology transfer process. MoDOT provided all the equipment for scanning and acquiring imagery of the concrete samples, including the analysis computer. Further, MoDOT provided staff to support the effort, and a funds-in payment of \$80K to supplement KCP efforts. The KCP contributed the expertise of their personnel and \$100K towards the project. In this joint effort, MoDOT personnel were closely involved with the development activities. MoDOT personnel had to learn about image processing and image acquisition in order to fully grasp the possibilities and constraints of the technology. KCP personnel learned enough about concrete properties and the concrete evaluation process to develop a scanning and analysis approach to replace the tedious manual method. As a result, MoDOT and KCP added breadth to their technical capabilities and gained significant knowledge in new technology areas.

Final Results:

This project resulted in the development of a prototype imaging and analysis system to evaluate the properties of Portland cement concrete. Additional system validation and software development continues to ensure that the system provides evaluation results within a satisfactory level of agreement with the MoDOT experts. However, the system hardware and software can presently be used as a baseline system to develop integrated analysis approaches for other applications in the concrete, transportation, or related industrial areas. At present, MoDOT and the KCP have signed a second CRADA to optimize the analysis software used to perform the concrete evaluation. Follow-on development of the baseline system is being considered. The goal of this follow-on effort is to improve the performance of the baseline system to a point where the automated approach replaces the current ASTM (manual) method. As many members of the concrete industry require the periodic evaluation of the quality of concrete products, adoption of the automated process as the new ASTM standard will improve the efficiency of this process industry-wide.

Tangible Benefits to Industry or State/Local Governments:

At present, MoDOT is the primary recipient of this technology. However, since the developed system reduces the amount of tedious effort for human operators, this system would be in high demand for any organization wishing to reduce manpower, reduce cost, or increase efficiency of their scanning and evaluation processes. The potential for commercial use is high. There are several groups within the transportation and construction industries that can gain

from the process improvement offered with this CRADA. These include:

- **The construction industry.** The concrete evaluation system could be used by construction firms and by evaluations/standards labs to assess the quality of concrete for construction projects. This group represents hundreds of potential customers for this technology.
- **The software industry.** The unique software techniques developed with this CRADA could be modified and customized for other imaging, surface profiling, and pattern recognition applications within a variety of industries, such as manufacturing and inspection. This group represents thousands of potential customers.
- **The medical industry.** The prototype system developed for concrete evaluation could be modified for use with microscope slides and the image analysis and pattern recognition software optimized for the analysis of medical imagery. This group numbers hundreds of potential customers.

- **Federal agencies.** The Federal Highway Administration (FHWA), and the Federal Aviation Administration (FAA) could use the system to assess the quality of concrete on all transportation facilities. The Department of Defense (DOD) might use it to evaluate materials for hardened facilities and military construction projects.

For more KCP information on this report contact:

Chris Baumgart
(505) 844-2585

Joe Whited
Office of Business Partnerships
Honeywell
(816) 997-2818

Patty Lemongelli
Missouri Department of Transportation
(573) 526-4328
e-mail: lemonp@mail.modot.state.mo.us